

Technology Readiness Assessment Summaries



Office of Technology Innovation and Development

Office of Environmental Management

September 2011

Technology Readiness Assessment Summary

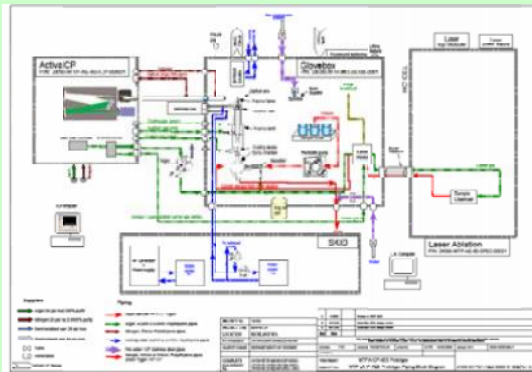
<u>Number</u>	<u>Title</u>	<u>Report Date</u>
TRA-1	Waste Treatment and Immobilization Plant (WTP) Analytical Laboratory, Balance of Facilities and LAW Waste Vitrification Facilities at Hanford	March 2007
TRA-2	Waste Treatment and Immobilization Plant (WTP) HLW Waste Vitrification Facility at Hanford	March 2007
TRA-3	Waste Treatment and Immobilization Plant (WTP) Pretreatment Facility at Hanford	March 2007
TRA-4	K Basins Sludge Treatment Process at Hanford	August 2007
TRA-5	Savannah River Site Tank 48H Waste Treatment Project at SRS	July 2007
TRA-6	233Uranium Downblending and Disposition Project at Oak Ridge/ORNL	September 2008
TRA-7	SRS Salt Waste Processing Facility at SRS	July 2009
TRA-8	K Basins Sludge Treatment Project Phase 1 At Hanford Richland Operations/RL	November 2009
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TRA-10	TRA of the Small Column Ion Exchange (SCIX) Program at SRS	November 2011

Technology Readiness Assessment Summary

United States Department of Energy Office of Environmental Management (DOE-EM)

Waste Treatment and Immobilization Plant (WTP) Analytical Laboratory, Balance of Facilities and LAW Waste Vitrification Facilities

Why DOE-EM Did This Review



Schematic of Laser Ablation Analytical Subsystem

DOE is constructing a Waste Treatment and Immobilization Plant (WTP) at Hanford to treat the site's tank wastes. The WTP is composed of several facilities including an Analytical Laboratory (LAB), Balances of Facilities (BOF) operations, and Low-Activity Waste (LAW) Vitrification Facility. The purpose of this assessment was to identify the critical technology elements (CTEs) in the abovementioned facilities (LAB, BOF, and LAW) and determine if these are sufficiently mature to be incorporated into the final WTP design, which normally requires a Technology Readiness Level of 6.

What the TRA Team Found

The assessment team identified the following CTEs, along with each element's Technology Readiness Level (TRL) for the LAB, BOF and LAW facilities:

- Two LAB systems were CTEs:
 1. Autosampling System (TRL=6), and
 2. Laser ablation analysis system: LA-ICP-AES/LA-ICP-MS (TRL=5)

- No BOF systems were CTEs
- Five LAW systems were CTEs:
 1. LAW Melter Feed Process System (TRL=6),
 2. LAW Melter System (TRL=6),
 3. LAW Offgas and Vent systems: LOP/LVP (TRL=6),
 4. LAW Container Sealing Subsystem (TRL=5), and
 5. LAW Decontamination Subsystem (TRL=4)

The team concluded that the CTEs are "sufficiently mature to continue to advance the final design."

What the TRA Team Recommended

The assessment team recommended the following:

- Testing the LAB's Laser Ablation Atomic Emission Spectrometry subsystem using actual waste samples to demonstrate the achievable detection limits and turnaround times.
- Testing the LAW's container inert filling, flange cleaning, inspection, and lidding/delidding system in a simulated remote environment to verify the equipment performs as required.
- Integrating testing of the LAW's container decontamination and smear testing systems in a simulated remote environment to verify the equipment performs as required and can achieve the specified decontamination levels. This testing should be supplemented with laboratory-scale testing to define the operational parameters for the CO₂ decontamination system.
- Identify and qualify a LAW melter bubbler design using material other than high nickel MA 758 alloy to mitigate the risk associated with the availability of this alloy.

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United States Department of Energy Office of Environmental Management (DOE-EM)

Waste Treatment and Immobilization Plant (WTP) HLW Waste Vitrification Facility

Why DOE-EM Did This Review



HLW Waste Vitrification Facility

DOE is constructing a Waste Treatment and Immobilization Plant (WTP) at Hanford to treat the site's tank wastes. The WTP is composed of several facilities including a High-Level Waste Vitrification Facility (HLW). The purpose of this assessment was to identify the critical technology elements (CTEs) in the HLW and determine if these are sufficiently mature to be incorporated into the final WTP design, which normally requires a Technology Readiness Level of 6.

What the TRA Team Found

The assessment team identified the following CTEs, along with each element's Technology Readiness Level (TRL) for the HLW facilities:

- HLW Melter Feed Process System (TRL=6)
- HLW Melter Process System (TRL=6)
- HLW Melter Offgas Treatment Process System/Process Vessel Vent System (TRL=5)
- Pulse Jet Mixer System/Rad Liquid Waste Disposal System (TRL=4)

The assessment team concluded that the CTEs of the HLW Vitrification Facility are sufficiently mature to continue to advance the final design.

What the TRA Team Recommended

The assessment team recommended the following:

- Testing the prototype HLW film cooler and film cooler cleaner to demonstrate the adequacy of the equipment in a melter equipped with bubblers

blockages in the cooler) prior to cold

understand the conditions (feed concentrations, bubbling rate, bubbler locations, etc.) that increase film cooler blockages would be useful.

- Testing and analysis of the Wet Electrostatic Precipitator (WESP) to demonstrate equipment adequacy (WESP electrode power) when processing Hanford waste and evaluating the corrosion resistance of the 6% molybdenum stainless steel internals of the WESP.

contacted with organics, acids (NO_x, SO_x, halogens), sulfur and mercury.

- Testing the pulse jet mixers for dissipating gases, blending liquids, and suspending solids. Specific requirements for pulse jet mixing should be established.

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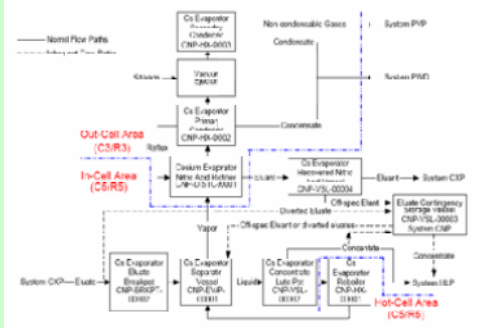
Technology Readiness Assessment Summary

United States Department of Energy Office of Environmental Management (DOE-EM)

Waste Treatment and Immobilization Plant (WTP) Pretreatment Facility

Why DOE-EM Did This Review

Figure 6-1-Basic Flow Diagram for the Cesium Nitric Acid Recovery Process System (CNP)



Block Diagram of Cesium Nitric Acid Recovery

DOE is constructing a Waste Treatment and Immobilization Plant (WTP) at Hanford to treat the site's tank wastes. The WTP is composed of several facilities including a Pretreatment Facility. The purpose of this assessment was to identify the critical technology elements (CTEs) in the Pretreatment Facility and determine if these are sufficiently mature to be incorporated into the final WTP design.

What the TRA Team Found

The assessment team identified the following nine CTEs, along with each element's Technology Readiness Level (TRL) for the Pretreatment Facility:

- Cs Nitric Acid Recovery Process System (TRL=3)
- Cs Ion Exchange Process System (TRL=5)
- Waste Feed Evap Process System (TRL=4)
- Treated LAW Evap Process System (TRL=4)
- Ultrafiltration Process System (TRL=3)
- Pulse Jet Mixer System (TRL=4)
- Waste Feed Receipt Process System (TRL=4)
- HLW Lag Storage (TRL=4)
- Plant Wash and Disposal System (TRL=4)

The assessment team concluded that several CTEs required maturity prior to continued design.

What the TRA Team Recommended

The assessment team generated an extensive list of recommendations. The following are the "major" recommendations; (the team also supplied 12 "supplemental" recommendations):

- Discontinue design of the Cesium Nitric Acid Recovery Process (CNP) until: (1) a reassessment of the design and operational requirements is completed, (2) the engineering specification is revised to reflect operational conditions, and (3) the technology concept is demonstrated through integrated prototype testing.
- Testing the CNP prior to installation in the black cell using representative feed compositions to verify the process control concept and the ability to control and monitor the composition of the nitric acid product, and to demonstrate the Cs decontamination factor of one million and the ability to decontaminate the demister pads.
- Discontinue design of the H₂ venting subsystem of the Cs ion exchanger until testing is completed.
- Evaluate the adequacy of feed vessel CXP-VSL-00001 design considering the anticipated issues with precipitation of solids in the feed.
- Complete testing of the Ultrafiltration Process (UFP) system prior to final design using actual wastes in laboratory tests and with stimulants at engineering-scale tests.
- Continue evaluation of vertical equipment arrangement for UFP filter elements.
- Establish clear, quantitative, and documented mixing requirements for all Pulse Jet Mixer (PJM) vessels in the Pretreatment as well as HLW Vitrification facility.
- Complete demonstration testing of PJMs, identify and implement any design changes.

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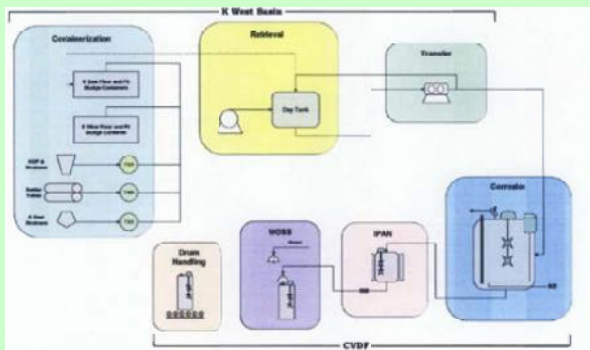
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United States Department of Energy Office of Environmental Management (DOE-EM)

K Basins Sludge Treatment Process

Why DOE-EM Did This Review



K Basins Sludge Treatment Process Flow Diagram

DOE is constructing a K Basins Sludge Treatment Process (STP) for retrieving, treating, and packaging the various sludge streams stored in the K West Basin at Hanford. The STP is comprised of seven major subsystems: sludge containerization, retrieval, transfer, oxidation, assay, packaging, and drum handling. The objective of the assessment was to perform a "finding-of-fact" appraisal of the project's overall technical maturity by first identifying the Critical Technology Elements (CTEs) of the process then evaluating the Technology Readiness Level (TRL) of each element.

What the TRA Team Found

The assessment team identified seven CTEs, each of which was further divided into sub-elements. The seven CTEs and the associated TRLs are listed below:

- Material Mobilization (TRL=2)
- Material Transfer (TRL=4)
- Process Chemistry (TRL=2)
- Process Instrumentation (TRL=4)
- Assay (TRL=2)

- Mixing (TRL=2)
- Waste Package (TRL=4)

The team concluded that the critical technologies associated with the Sludge Treatment Process are not at the maturity level required to support Critical Decision-3 (CD-3) for procurement and construction, but are more appropriately between CD-0 and CD-1.

What the TRA Team Recommended

The team noted that one of the primary barriers of establishing higher TRLs relates to unknowns associated with the physical properties of the containerized and/or oxidized sludge. Because of this a representative simulant for testing and demonstration of process technologies has not been developed.

Results of the assessment show that while the overall Critical Technology Element maturity levels may be low, several technology sub-elements are at relatively high maturity level. This indicates the need for (and the team recommends) a targeted maturation plan that focuses on those technologies requiring further maturity.

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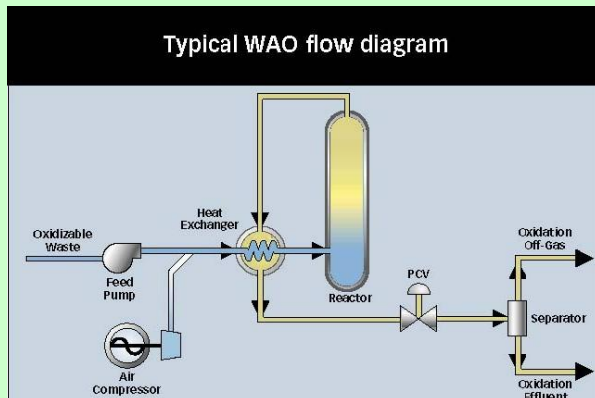
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United States Department of Energy Office of Environmental Management (DOE-EM)

Savannah River Site Tank 48H Waste Treatment Project

Why DOE-EM Did This Review



Wet Air Oxidation Process

Savannah River Tank 48H is a 1.3 million gal tank containing approximately 250,000 gal of high-level liquid waste. The waste is a salt solution that also contains tetraphenylborate (TPB), which can release potentially flammable concentrations of benzene vapor to the tank head space. Two potential treatment options have been identified for this organic-bearing tank waste: Wet Air Oxidation (WAO) and Fluidized Bed Steam Reforming (FBSR). This assessment was conducted to aid in deciding which technology should be pursued for treating the Tank 48H waste.

What the TRA Team Found

The assessment team determined the Critical Technology Elements (CTEs) and the associated Technology Readiness Level (TRL) for each process, as listed below:

- Wet Air Oxidation Process:
 - Reactor system (TRL=3)
 - Offgas Treatment System (TRL=2)

- Fluidized Bed Steam Reforming Process:
 - Steam Reformer System (TRL=4)
 - Offgas Treatment System (TRL=4)
 - Product Handling System (TRL=3)

The team concluded that both WAO and FBSR are viable technologies for treating the Tank 48H waste. FBSR is more advanced; however, both require technology maturity. The team noted that it would be preferred to choose one primary technology to receive the bulk of the effort and investment, while the other could be carried at a significantly lower investment and be used as a back-up to the primary.

What the TRA Team Recommended

The team recommended the following for the WAO process:

- The reactor should undergo pilot-scale testing with simulants, laboratory-scale testing with actual wastes, and concept development to support design implementation.
- The offgas system should undergo laboratory and bench-scale testing with actual wastes (if practical). However, if using actual waste is not feasible in laboratory tests, offgas testing using tracers at commissioning should be considered.

The team recommended the following for the FBSR process:

- The Steam Reformer Subsystem requires further testing of the cyclone downcomer and other components.
- Testing and development of the Product Handling System is required to demonstrate transferring material at the wt% levels anticipated for plant operations. In addition, technical issues have been identified with meeting acceptance criteria for the tank farm that may require wet product sieving and/or waste blending.

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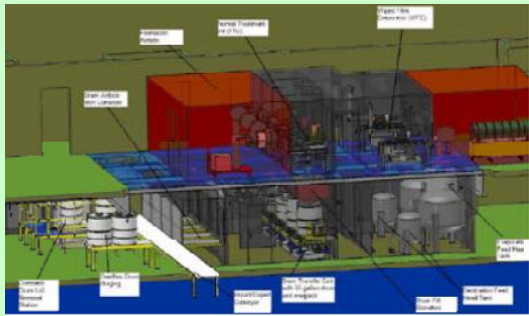
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United States Department of Energy Office of Environmental Management (DOE-EM)

²³³Uranium Downblending and Disposition Project

Why DOE-EM Did This Review



Product Packaging System and Interfaces

EM was directed to take ownership of a facility housed in Building 3019 at Oak Ridge that was originally used to extract ²²⁹Th (an isotope used in medical research) from ²³³U. The mission, after takeover by EM, was to downblend the inventory of ²³³U in Building 3019 to mitigate security and safety (especially criticality) concerns and prepare the material for transport and disposal. The project anticipated that the downblended material could be disposed at either WIPP or the Nevada Test Site. This assessment was conducted to coincide with the 30 design review for the “back-end” of the downblending process, thereby allowing observations and issues identified by the assessment team to be included in the project technology maturity plans and/or design review.

What the TRA Team Found

The assessment team identified the following Critical Technology Elements (CTEs) and the associated Technology Readiness Level (TRL):

- Analytical Laboratory (TRL=3)
- Concentration process - Wiped Film Evaporator (TRL=4)
- Product Packaging (TRL=3)
- Offgas Treatment (TRL=2)

The team also identified a significant risk to the project's mission, which was centered on the uncertainty of the ²³³U concentration in the source material. Downblending the ²³³U may reduce the transuranic (TRU) content of the waste to below 100 nCi/g, which is the minimum TRU content acceptable at WIPP. Waste below this TRU level may be acceptable at the NTS, however, this facility was scheduled to close (year 2010) prior to the blending operations being completed. Thus WIPP was the only foreseeable pathway for disposition of the ²³³U waste disposition, although the produced material may not meet acceptance criteria.

What the TRA Team Recommended

The team made the following recommendations:

- The project (**Analytical Lab**) should develop a detailed sampling and analysis plan to support process control, production schedule, etc.
- The project (**Analytical Lab**) should develop a complete set of data quality objectives that identify requirements for turn-around times, detection limits, precision/accuracy derived from disposal criteria, etc.
- Test the **Wiped Film Evaporator** with simulated waste to provide performance data.
- Test the integrated **Product Packaging** system with granular/powder simulants and with multiple repetitions of transfers (assess solids build-up on surfaces); develop a “tightly specified” acceptance criteria.
- For **Offgas Treatment** the project needs to either demonstrate that the proposed design will capture the fine particles evolved as daughter products from ²²⁰Rn or modify the design (incorporating other CTEs) that ensure capture of these.

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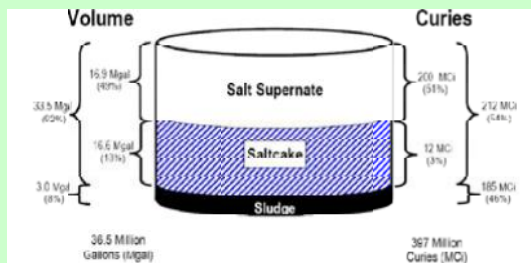
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United States Department of Energy Office of Environmental Management (DOE-EM)

SRS Salt Waste Processing Facility

Why DOE-EM Did This Review



SRS Composite High Level Waste Inventory

DOE Savannah River is constructing a Salt Waste Processing Facility (SWPF) to separate and concentrate targeted radionuclides (Cs-137, Sr-90, and actinides) from High Level Waste (HLW) salt solutions in a series of unit operations. Sr and actinides are removed by contacting the waste solution (after feed adjustment) with a monosodium titanate (MST) solid sorbent in a batch mixer using air pulse agitators. The sorbent (containing Sr and actinides) is removed from solution by cross flow filtration. The filtered solution is passed to a solvent extraction process where Cs is separated to an aqueous (strip solution) effluent stream. The bulk solution (the raffinate) from the extraction process, with targeted nuclides removed to sufficiently low level, is disposed as Saltstone. The separated high activity streams: the MST adsorbent (with Sr and actinides) and the Cs effluent, are sent for vitrification in the Defense Waste Processing Facility (DWPF). Provisions are in place to perform a second Sr/actinides adsorption step if necessary. The SWPF federal project director requested this assessment to assure that the planned technologies are adequate and have been matured to levels consistent with Critical Decision-3 approval.

What the TRA Team Found

The team identified eight Critical Technology Elements (CTE) of the SWPF which are listed below with a brief description. All CTEs were assigned a Technology Readiness Level of 1.

- Aluminum Chemistry – feed solution adjustments may be required for processing, but could result in undesirable precipitation of Al compounds.
- Air Pulse Agitator – provides a well mixed suspension of MST solids in the salt waste solution.
- Cross Flow Filter – retains the MST sorbent (with Sr and actinides) resulting in a ~5wt% slurry.
- Caustic-Side Solvent Extraction (CSSX) Chemistry – selectively separates Cs from the bulk salt waste solution and produces a Cs-bearing aqueous stream suitable as feed for vitrification and a bulk salt waste (raffinate) suitable as feed for saltstone.
- Centrifugal Contactors – provides continuous extraction of Cs from the bulk salt waste solution.
- Extraction Solvent Recovery – recovers entrained, high-valued organic solvent from the aqueous product streams.
- MST/Sludge Handling – suspends and transports sludge to the melter.
- Process Integration – evaluates how well all subsystems perform with each other and with other on-site facilities.

What the TRA Team Recommended

The team provided the following recommendations:

- Continue study of operating limits to prevent and/or minimize solids for action in feed adjustment and solvent extraction systems.
- An integrated liquid waste systems model should evaluate the impacts on the SWPF and the entire liquid waste system of the Al in sludge being diverted from the DWPF feed to the SWPF feed.
- Interaction and communication between the SWPF project and existing Integrated Salt Disposition Project should continue and be enhanced as much as possible in the future. Exchange of personnel between the projects should be considered.

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K Basins Sludge Treatment Project Phase 1

Why DOE-EM Did This Review



XAGO HydroLance spray demonstration

The mission of the Sludge Treatment Project (STP) is to retrieve, treat, and package sludge from the K Basins of Hanford for disposal at a national repository. The sludge resulted from washing and packaging of spent nuclear fuel and material cleaned up from the K East and K West Basin floors. The sludge is stored in the K West Basin in Engineered Containers (ECs) and settler tanks (STs). Phase 1 activities include: (1) retrieving sludge from the ECs and placing it in Sludge Transport Storage Containers (STSCs), (2) decanting and filtering excess water from the sludge, and (3) transporting the sludge-loaded STSCs to the Hanford Central Plateau for interim storage pending completion of future treatment and packaging capabilities (Phase 2). An additional feature of Phase 1 is the option of removing excess sludge from an STSC if overfilling occurs. This assessment was conducted to support Critical Decision-1 approval for Phase 1 of the project. In addition, the assessment team evaluated remedialization activities, which will be used in Phase 2.

What the TRA Team Found

The team identified three Critical Technology Elements (CTEs) that are described below. Each was assessed a Technology Readiness Level (TRL) of 4.

- **Xago HydroLance Tool:** commercially available device (combine fluidizer and jet pump) used to retrieve sludge from the ECs in Phase 1 and from the STSCs in Phase 2.
- **Overflow Recovery Tool:** a direct suction lance with a mobilizing spray nozzle similar to Settler Retrieval Tool installed in the K West Basin Settler Tanks used to remove excess sludge from an STSC.
- **Booster/Decant Pump:** a peristaltic hose pump used to transfer abrasive slurries and debris for service submerged in basin water.

The integrated process system was assigned a TRL of 4- because the final waste form and disposal path for the sludge (Phase 2) has yet to be determined.

What the TRA Team Recommended

The team provided the following recommendations:

- Continue the planned test programs including the maintenance and storage facility prototype tests and the submerged pump tests.
- Continue sludge aging studies, note the effects of U metal oxidation and multi-year storage on sludge properties. Periodically sample STSCs while in storage. Develop a program to monitor and predict sludge property changes during storage period as necessary input for Phase 2.
- Search for new characterization methods to aid in evaluation of sludge transport.
- Continue the program for process improvements, for example flocculants, turbidity, and in-situ measurements.
- Proceed with Phase 2 process development as soon as possible.

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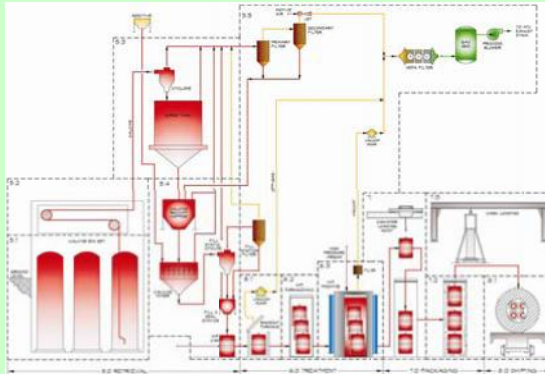
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United States Department of Energy Office of Environmental Management (DOE-EM)

Preliminary TRA of the Calcine Disposition Project

Why DOE-EM Did This Review



Calcine HIP Treatment Process Flow Diagram

The Idaho high-level waste calcine is solid granular material designated through an amended ROD (issued Dec. 2009) to undergo treatment by a Hot Isostatic Press (HIP) process. The HIP process, possibly with additives, converts the calcine to a monolithic waste form with durability and leach rates comparable to those of borosilicate glass. The calcine disposition

anticipates Critical Decision-1 (CD-1) approval in late 2012 authorizing the preliminary design phase. For CD-1 approval, it is typically recommended that the selected technology be at a Technology Readiness Level (TRL) of 4 or higher. The objective of this assessment was to identify the Critical Technology Elements (CTEs) of the HIP treatment process and assign the TRLs that are anticipated by late 2010 in preparation for CD-1.

What the TRA Team Found

The assessment team identified the eleven CTEs listed below along with the associated TRLs expected to be achieved prior to CD-1 (now scheduled for 2012):

- Retrieval/Pneumatic Transfer System (TRL=4)
- Batching and Mixing System (TRL=4)
- Ceramic Additive Formulation (TRL=3)

- Hot Isostatic Pressing Can Design (TRL=3)
- Hot Isostatic Pressing Can Containment (TRL=2)
- HIP Can Filling and Closure (TRL=4)
- Bakeout System (TRL=4)
- Canister loading/Closure (TRL=4)
- Remote Operation and Maintenance (TRL=4)
- Characterization: feed, admixture, product (TRL=4)
- Simulant Formulation (TRL=3)

The team identified several significant project risks, among which were the following:

- Design of the facility is being restricted to the Integrated Waste Treatment Unit (IWU) footprint for systems requiring Performance Class-3 construction; meeting this requirement and the December 2035 completion date will be a challenge.
- If additional sampling of calcine is required, designing and constructing the facility within the IWU footprint may be impractical.

Significant supporting documentation was not available to the assessment team at the time of the review. A follow-up assessment will be required prior to CD-1.

What the TRA Team Recommended

- The project should ensure that all required documents are complete and available to the review team for all future assessments.
- The project should complete discussions of waste form requirements with the EPA and EM as soon as possible.
- A full-scale mockup facility should be built and operated to achieve a TRL of 6 for CD-2.
- The project's technology maturity plan should identify all necessary development work and address achieving a TRL of 6 for all CTEs prior to CD-2.

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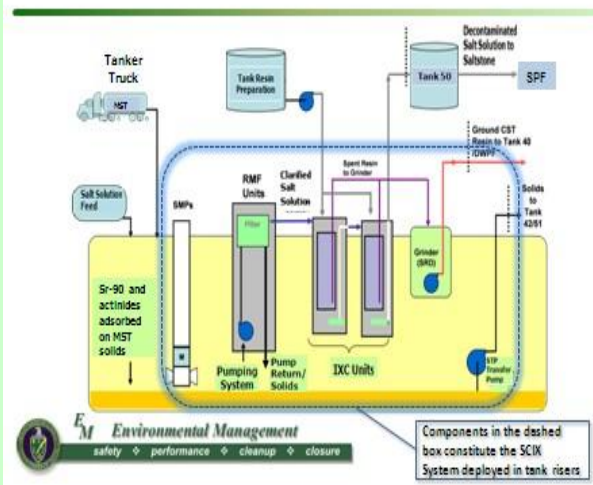
Technology Readiness Assessment Summary

United States Department of Energy Office of Environmental Management (DOE-EM)

TRA of the Small Column Ion Exchange (SCIX) Program

Why DOE-EM Did This Review

Technology Description



SCIX Process Flow Diagram

The SCIX system being developed for deployment at the Savannah River Site is a supplementary salt waste processing technology that, if implemented, will augment the baseline Salt Waste Processing Facility (SWPF) capability. The SCIX system, in combination with deployment of a Next Generation Solvent in the SWPF, is projected to provide nearly \$3B in cost savings due to schedule acceleration and elimination of "salt waste only" processing in the Defense Waste Processing Facility.

This TRA was unique in that the SCIX Program is a Technology Demonstration Operations Activity, and not a formal project, as defined in DOE Order 413.3A. Thus, correlation with Critical Decisions is not applicable; however, similar requirements were implemented by the SCIX Program Team.

This TRA was conducted to document the technical maturity of the SCIX system and validate the activities remaining to mature the technology to a Technology Readiness Level (TRL) 6.

What the TRA Team Found

The TRA team identified the four CTEs listed below, along with the associated TRLs for each:

- Large Tank Monosodium Titanate Strike (TRL=5)
- Rotary Microfilters (TRL=5)
- Ion Exchange Columns using Crystalline Silicotitanate (TRL=5)
- Spent Resin Disposal (Grinder) (TRL=3)

The overall TRL is 3. Completion of the full scale design for the Grinder will result in an overall TRL 5 for the SCIX system. A full scale integrated system test is required to achieve TRL 6.

What the TRA Team Recommended

1. At a minimum, the following few, relatively low-cost, activities (as compared to the full set of activities required to attain TRL 6) should be completed.
The detailed vendor technology designs should be completed for all CTEs
Interface designs to integrate the CTE components and other equipment into a system should be finalized.
The Preliminary Documented Safety Analysis should be completed.
2. The scope, cost, and schedule estimate should be completed for the technology development and testing required to attain TRL 6, and documented in a revision of the Technology Maturation Plan (TMP).

Implementing these recommendations would better position the program to facilitate a quick and cost effective implementation. Having the completed full scale design and PDSA would provide the validated documentation to immediately transition to fabrication and integrated testing.

To view the full TRA reports, please visit this web site:
<http://www.em.doe.gov/Pages/ExternalTechReviews.aspx>

TRA Summary: November 2011

The objective of a Technology Readiness Assessment (TRA) is to determine the maturity of certain key technologies, identified as Critical Technology Elements (CTEs), using a systematic, metric-based process and to evaluate the readiness of these technologies for insertion into a project design.



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